Improved and electronically timed Zimm–Crothers type viscometer

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Abstract The torque adjusting mechanism of a Zimm–Crothers type viscometer was made more convenient, reproducible and precise by use of a fixed stator, an adjustable magnetic drive yoke and spacer blocks. A photoelectric device was added for timing the rotor speed and counting the revolutions. A photoconductive cell, associated optics, relays, an electric timer and an electrically triggered counter contribute a degree of automation to the viscometer.

1 Introduction

A low shear viscometer of the Zimm–Crothers type is extremely useful for measuring shearing stress of liquids (from about 0·0001 to 0·3 dyn cm^{-2}) as a function of shearing rate (from about 0·01 to 30 s^{-1} with water). The viscometer consists of a glass test tube (rotor) that floats on the liquid medium under investigation, which is contained in an outer fixed glass test tube (stator). A constant torque is applied to the rotor by a rotating magnetic field that interacts with a steel pellet in the bottom of the rotor. The speed of the rotor relative to the stator is measured. Zimm and Crothers (1962) described an instrument of this type employing separate rotors with different size pellets for each shear stress. Subsequently, a commercial version of this viscometer was made available (Beckman Instruments, Inc., Spinco Division, 1117 California Avenue, Palo Alto, California 94302).† Its design features eliminated the need for separate rotors. The change in driving force is achieved by raising or lowering the stator–rotor unit. This procedure, however, is inconvenient and can very easily result in improper alignment and levelling, producing errors in the measurement. In addition, the rotor speed is manually determined. Reported herein is a simple mechanical arrangement for adjusting the torque and a device for electrically measuring the rotor's speed and counting revolutions, using the commercial viscometer.

2 Mechanical improvements

In order to improve the mechanism for changing the torque, the drive yoke was made adjustable as shown in figure 1. The yoke telescopes on to an oversized (0·375 in) motor shaft. Nylon set screws oppositely placed near the bottom of the hub hold the yoke in position on the motor shaft. This arrangement permits the drive yoke to be adjusted vertically with respect to the bottom of the fixed stator and therefore the steel pellet in the bottom of the rotor. Its adjustment range is 32·5 mm. The adjustable drive yoke must be dynamically balanced to prevent excessive vibration when it is fully extended on the motor shaft. As an additional precaution against excessive vibration, the motor mount was reinforced. Levelling of the stator–rotor unit is made convenient by using a circular bubble level mounted on a flanged brass plug that fits snugly into the top of the stator.

† The mention of commercial items is for the reader's convenience and does not constitute an endorsement by the Department of Agriculture over others of a similar nature not mentioned.

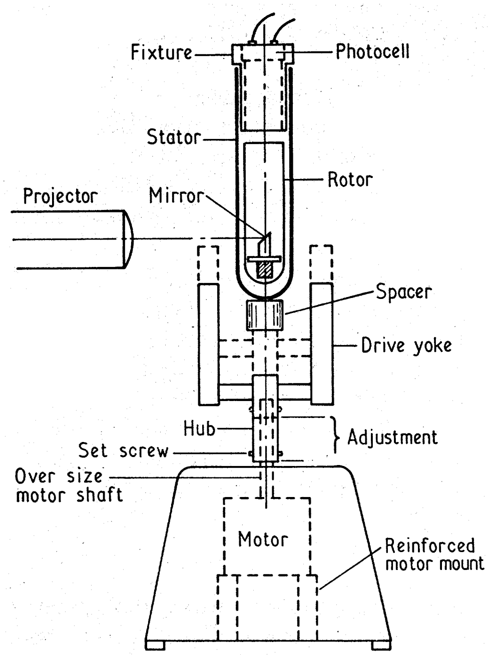

Figure 1 Sketch showing adjustable drive yoke and arrangement of timing components

Accurate adjustment of the magnetic yoke with respect to the rotor pellet is obtained simply by interposing spacing blocks between the bottom of the stator and the flattened squared-off top of the yoke hub, as shown in figure 1. This method of adjustment dispenses with the cathetometer employed by Zimm and Crothers, and therefore is simpler, more convenient and more repeatable. Spacer (gauge) blocks with an accuracy to $\pm 0{\cdot}003$ mm constructed of cold rolled steel bar stock were used.

3 Rotor timing scheme

A timing arrangement was designed that required but one revolution of the rotor for making an accurate measurement. The timer used has a resolution of 0·001 min and an actuation time of 10 ms; the photocell-relay system has an approximate response time of 50 ms. A cadmium sulphide photoconductive cell (figure 1) with a maximum power dissipation of 600 mW and a resistance range from 2750 to 200 Ω is employed as a transducer. The photocell is held in the flanged end of a hollow cylindrical fixture whose inside wall is nonreflecting black. This fixture aligns the cell with a ($\frac{1}{8}$ in diameter) first surface mirror which is resting on the pellet at the bottom of the rotor. This mirror is concentric with and at a 45° angle to the viscometer axis. The photocell looks at this mirror which is illuminated by a projected filament image of a 12 V bulb. The full area of the photocell should be illuminated for maximum response. The projector is fastened to the upright bar of the viscometer stand by means of a special bracket which permits it to be adjusted both vertically and horizontally for alignment and focusing. The photocell responds each time the mirror is fully illuminated by the filament image. The light-induced signal from the photocell energizes a relay system which triggers an electric timer and a counter. The timer continues to operate until the counter reaches a preset value; then the apparatus automatically shuts off.

4 Experimental check of the timing measurements

A comparison of the electrically timed (stopwatch) measurements was made using distilled water at $20 \pm 0{\cdot}2$°C and for one revolution of the rotor. Three drive yoke-stator separations were used and the time/revolution ranged from 25·28 to 74·35 s. The results of six measurements shown in table 1 reveal, as expected, that electronic timing is more precise than manual timing.

Table 1 Comparison of electronic with manual time measurements

Test run	Separation of drive yoke hub and stator: 20·0 mm E (s)	20·0 mm M (s)	27·5 mm E (s)	27·5 mm M (s)	32·5 mm E (s)	32·5 mm M(s)
1	25·62	25·3	42·06	42·2	74·04	74·5
2	25·62	25·1	42·12	41·6	73·98	74·0
3	25·65	25·3	41·88	42·0	74·04	74·3
4	25·56	25·1	42·00	41·8	74·04	74·6
5	25·50	25·6	41·88	41·4	74·04	74·8
6	25·56	25·2	41·88	41·8	74·98	73·9

E, electronic; M, manual

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References

Zimm B H and Crothers D M 1962 *Proc. Nat. Acad. Sci. US* **48** 905